American Journal of Sciences and Engineering Research
E-ISSN - 2348 -703X, Volume 4, Issue 3, 2021

Modeling the Start, Length and End of "Tsioka Atimo" Wind Season in Southern of Madagascar Using Fuzzy Time Series

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Abstract: *Our research work consists in modeling the start, length and the end of the "Tsioka Atimo" wind season in the South of Madagascar using the Chen's method (1996) for fuzzy time series. It is a first-order model and the number of partitions is the only adjustable parameter of the model. The start, length and end of wind season are important information in the study of migratory locust movements in Southern of Madagascar. The Liebmann's method is applied to the daily wind speed series to determine the start, length and end of the wind. We consider the number of partitions as 10 then 50 then 100 partitions. Each partition corresponds to a model. Each model are evaluated by the differences between the observation and the forecast. We use the well-known Root Mean Square Error (RMSE) metric to evaluate the models. A low Root Mean Square Error corresponds to a good model. As a result, among the candidate models, Chen's method for fuzzy time series model with 100 partitions is the best for the start, length and end of "Tsioka Atimo" wind season in Southern of Madagascar.*

Key words: *Start of windy season, windy season length, end of wind season, Chen's method, fuzzy time series, Southern of Madagascar.*

I. Introduction

The South of Madagascar is an area of frequent occurrence of migratory locusts. For several weeks, locusts devour all the crops in the south of the island, threatening the meagre livelihoods of an already vulnerable population [1]. The locust invasion exacerbates the chronic famine problem in the area [2]. Since locusts move continuously from one place to another, the trajectory of the locust invasion is the parameter witch interest researchers. It is therefore of great importance to know how locusts movement. As locusts move through the air, the meteorological parameter wind is assumed to be the most influential parameter in the movement of locust invasions. In this area, the wind called "TsiokaAtimo" blows every year. The problematic that arises is how the start, length and end of this wind vary from year to year.

The solution of this problematic need the modeling. Statistics offers a multitude of types of models capable of modeling time series. For our case, we use Chen's method for fuzzy time series (1996) [3]. This is method is the application of the first fuzzy time series theory which the application of fuzzy logic invented by Lotfi Zadeh in [4] to time series [5].

 Received- 10-05-2021, Accepted- 20-05-2021

II. Materials and methods

2.1 Experimental data

We use wind reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF) [6] in the locust area (20°S to 26°S and 43°E to 47°E). We retrieve from ECMWF the daily meridional and zonal components of the wind with resolution 1°x1°. The temporal coverage of our datasets is from January, 1 1979 to December, 31 2017. From the meridian and zonal components of wind, we calculate the daily, then monthly, and annual wind speed at each grid point. For each year, we apply the Liebmann's method to the daily wind speed series to determine the start, length and end of the wind season.

Table 1, 2 and 3 below show the start, length and end of the wind season respectively.

Table 1: Datasets of start of "Tsioka Atimo" windy season

Year	Start of "Tsioka Atimo" windy season (Rank of the day from Janary,1st)
1979	163
1980	179
1981	89
1982	28
1983	161
1984	19
1985	40
1986	44
1987	101
1988	26
1989	54
1990	130
1991	44
1992	157
1993	57
1994	29
1995	20
1996	22
1997	21
1998	35
1999	176
2000	33
2001	67
2002	82
2003	160
2004	20
2005	72
2006	174
2007	51
2008	30
2009	81
2010	168
2011	29
2012	5

2013	21
2014	79
2015	3
2016	82
2017	65

Table 2: "Tsioka Atimo" windy season length

Year	Wind duration (In day)
1979	92
1980	109
1981	207
1982	68
1983	123
1984	103
1985	19
1986	35
1987	219
1988	77
1989	49
1990	184
1991	74
1992	128
1993	22
1994	39
1995	141
1996	101
1997	25
1998	23
1999	129
2000	35
2001	153
2002	261
2003	100
2004	159
2005	28
2006	140
2007	25
2008	54
2009	34
2010	113
2011	23
2012	59
2013	36
2014	25
2015	72
2016	164
2017	279

Table 3: End of wind "TsiokaAtimo

Year	End of windy season (Rank of the day from Janary,1st)
1979	255
1980	288
1981	296
1982	96
1983	248
1984	122
1985	59
1986	79
1987	320
1988	103
1989	103
1990	314
1991	118
1992	285
1993	79
1994	68
1995	161
1996	123
1997	46
1998	58
1999	305
2000	68
2001	220
2002	303
2003	260
2004	179
2005	100
2006	314
2007	76
2008	84
2009	115
2010	281
2011	52
2012	64
2013	57
2014	104
2015	75
2016	246
2017	320

2.2 Methodology

The pioneering of fuzzy time series is SONG and CHISSON (1993) [7] but we use here the evolution published by CHEN (1996) [3]. The idea is to divide the universe of time series discourse into intervals or partitions (fuzzy sets), and to learn how each area behaves (extract rules through time series models). The

rules in these models indicate how the partitions relate to themselves over time, as values jump from one place to another.

The methodology adopted is divided into three phases:

- The training phase ;
- The forecasting phase;
- The model evaluation phase.

a) The training phase

a.1) Definition of the universe of discourse U

The universe of discourse U is none other than the width of the statistical series with a 20% safety margin.

a.2) Partitioning the universe of discourse

In our study, we subdivide the universe of discourse into 10, then 50, then 100 partitions. Let Ã be the set of linguistic variables. Making n partitions consists in creating n fuzzy sets named $A_0, A_1, ..., A_{n-1}$

$$A = \{A_0, A_1, ..., A_{n-1}\}$$

a.3) Fuzzification

Fuzzification consists to convert the numerical values of X (t) (the time series to be modelled) into fuzzy values of the linguistic variable Ã, giving rise to the fuzzy time series F (t).

a.4) Creation of temporal models

A temporal model indicates two fuzzy sets which appear sequentially on fuzzy time series F (t) and have the format:

Precedent → Consequent,

Where the precedent indicate a fuzzy set at time t and the consequent, the fuzzy set which appears shortly after at time t + 1.

a.5) Creating rules

Our rules also have the format:

Precedent → Consequent.

Given the temporal patterns generated earlier, we will group them by its precedents. Our model will contain a rule for each distinct precedent found, and the consequent of each rule will be the union of all the consequents of each temporal pattern with the same precedent.

b) The forecasting phase

b-1) Fuzzification of the input value

The input value x (t) will be converted into fuzzy values of the language variable Ã, generating the value f (t). As in the training phase, only the most relevant set is chosen.

b-2) Find the compatible rules

Find the rule whose prior is equal to f (t). The consequence of the rule will be the fuzzy forecast for t + 1, i.e. f (t + 1).

b-3) Defuzzification

Defuzzification consists in converting the fuzzy value f (t+1) into a numerical value corresponding to the forecast value.

$$x(t+1) = n^{-1} \sum A_i$$

For i = 0...n-1 and n equals the number of fuzzy sets in f (t + 1).

c) The model evaluation phase

Each number of partitions corresponds to a model. The Root Mean Square Error (RMSE) is used to assess the difference between the observed data and the data from the model. The following formula allows us to calculate the RMSE:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}[X(t) - \overline{X}(t)]^2} \quad (2)$$

Where: n: number of observations
X(t) : The value observed at time t ;
$\bar{X}(t)$: The output value of the model corresponding to the forecast data at time t.

III. Results

Table 4 below gives us the RMSE values according to the number of partitions for the start of wind season. We find that the Chen's method for fuzzy time series model with 100 partitions is the best.

Table 4: RMSE according to the number of partitions for start of windy season

Number of partitions	10	50	100
RMSE	50,44	39.61	17.5

Table 5 below gives us the RMSE values according to the number of partitions for the case of windy season length. We note that once again, the Chen's method for fuzzy time series model with 100 partitions is still the best.

Table 5: RMSE according to the number of partitions for windy season length

Number of partitions	10	50	100
RMSE	62	37.58	23.18

Table 6 below gives us the RMSE values according to the number of partitions for the end of windy season. Again, the Chen's method for fuzzy time series with 100 partitions is recommended.

Table 6: RMSE according to the number of partitions for the end of windy season

Number of partitions	10	50	100
RMSE	83	52,03	52

Figure 1 below shows the results of the start of windy season modeling for 100 partitions. In blue we have the observed data and in orange the data from the model.

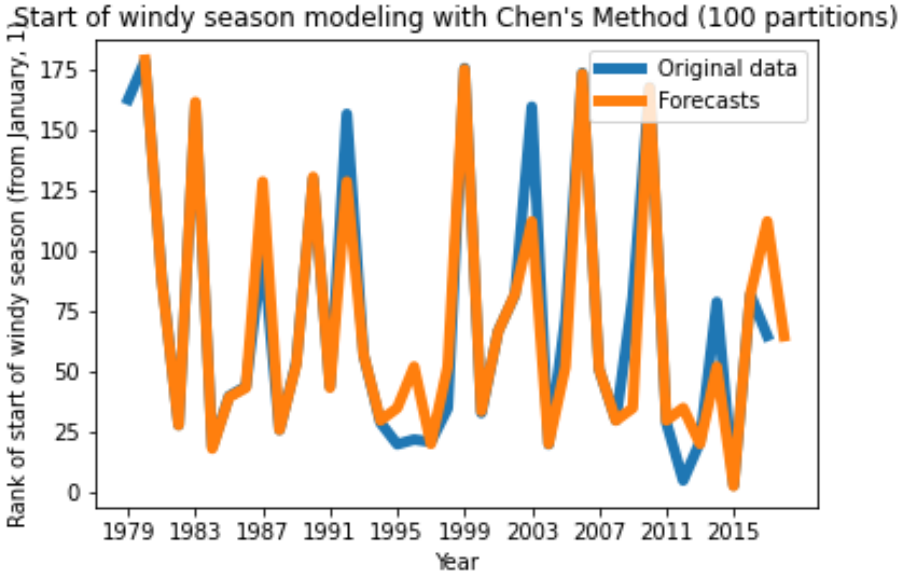

Figure 1: Result of the start of windy season modeling (100 partitions)

Figure 2 below shows the results of windy season length modeling for 100 partitions. In blue we have the observed data and in orange the prediction.

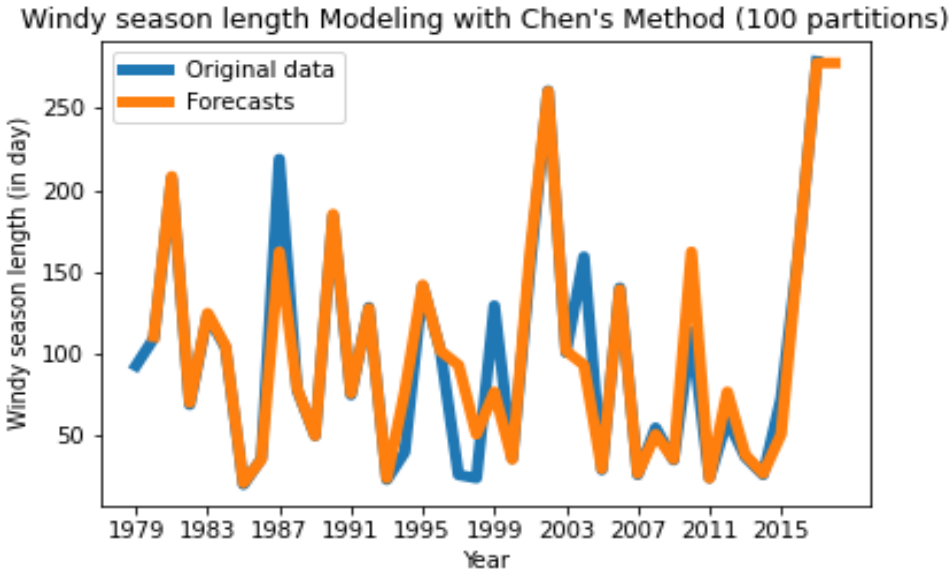

Figure 2: Result of windy season length modeling (100 partitions)

Figure 3 below shows the results of the end of windy season modeling for 100 partitions. In blue we have the observed data and in orange the prediction.

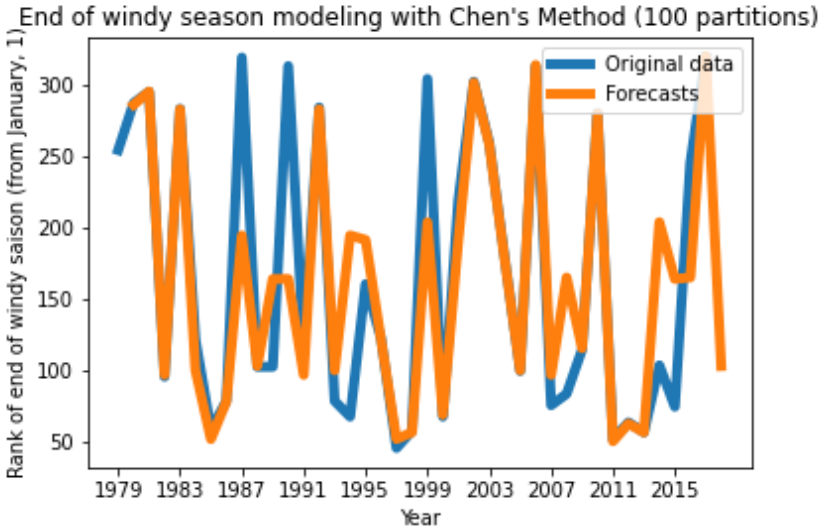

Figure 3: Result of the end of windy season modeling (100 partitions)

IV. Discussions

The Liebmann's method [8][9] is often used to determine the onset, end set and duration of the rainy season. In our work, we used it to determine the start, length and end of wind in Southern of Madagascar. Fuzzy time series modeling was used by CHEN for the first time in 1996 to model enrolment at the University of Albama, and other researchers used this model to model other types of annual data. We have used exactly this method to model the start of windy season, windy season length and the end of windy season in Southern of Madagascar. Note that there are many other variants of fuzzy time series models. In the context of our research, the number of partitions is the only parameter of the model. Other researchers add other

parameters such as the order of the model [10]. To evaluate the models obtained, we use the RMSE metric. Other metrics are also common such as MAE, MAPE, etc [11] [12].

V. Conclusion

The research about start wind season, windy season length and end of windy season is useful to analyze the movements of migratory locusts. The Chen's method invented in 1996 is used for modeling. It is a first-order model with a variable the number of partitions. We consider only 10, 50 and 100 as number of partitions. The difference between the forecast and the observation is appreciated by the Root Mean Square Error (RMSE) metrics. In all possible cases, the model with 100 partitions is the best.

VI. Références

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